CLAIMS

What Is Claimed Is:

1. An antimatter storage device for electrically neutral excited species of antimatter or exotic matter, said antimatter storage device comprising a three-dimensional or two-dimensional photonic bandgap (PBG) structure containing at least one PBG cavity in said PBG structure, said PBG cavity comprising a cavity wall embedded in said PBG structure and surrounded thereby and containing a quantity of species selected from the group consisting of excited electrically neutral atoms and molecules of antimatter, and excited electrically neutral atoms and molecules of exotic matter.

2. The antimatter storage device of Claim 1 wherein said PBG structure comprises materials and geometry that together provide bandgaps at frequencies specific to each species to be stored in said antimatter storage device.

3. The antimatter storage device of Claim 2 wherein said PBG structure has behavior that is dependent on a periodic contrast, wherein said periodic contrast is one-dimensional, two-dimensional, or three-dimensional, in the index of refraction between different constituent elements of said PBG structure, its geometry, and spacing associated with an arrangement of said constituent elements, and shapes of said constituent elements.

4. The antimatter storage device of Claim 3 wherein said material comprising said PBG structure is selected from the group consisting of inverse opal backbone, macroporous silicon, colloidal crystals, woodpile structure, Yablonovite, and the like.

5. The antimatter storage device of Claim 1 wherein said excited electrically neutral species is selected from the group consisting of positronium, antihydrogen, protonium, antimuonium, molecular positronium, molecules containing positronium, positronium molecules bound to ordinary matter, and electrically neutral molecules

containing a positron having a single positive charge bound to ordinary matter having a single negative charge.

6. The antimatter storage device of Claim 5 wherein said excited positronium comprises an electron and a positron bound together in orbit, but separated by a first distance, and wherein said excited positronium is separated from said cavity wall by a second distance.

7. The antimatter storage device of Claim 6 wherein said first distance is large enough to prevent self-annihilation but small enough to keep said electron and said positron in orbit about each other, and wherein said second distance is large enough to prevent contact of said excited positronium with said cavity wall.

8. The antimatter storage device of Claim 1 comprising an array of said PBG cavities, each PBG cavity separated from its nearest-neighbor PBG cavities by a third distance.

9. The antimatter storage device of Claim 8 wherein said third distance is less than the photon localization length.

10. The antimatter storage device of Claim 8 wherein said third distance is greater than the photon localization length.

11. A method of capturing antimatter, said method comprising:

providing an antimatter capture device comprising a three-dimensional or two-dimensional photonic bandgap (PBG) structure containing at least one PBG cavity therein, said PBG cavity capable of containing a quantity of species selected from the group consisting of excited electrically neutral atoms and molecules of antimatter, and excited electrically neutral atoms and molecules of exotic matter; and

introducing said species into said at least one PBG cavity.

12. The method of Claim 11 wherein said PBG structure comprises materials and geometry that together provide bandgaps at frequencies specific to each species to be stored in said antimatter storage device.

13. The method of Claim 12 wherein said PBG structure has behavior that is dependent on a periodic contrast, wherein said periodic contrast is one-dimensional, two-dimensional, or three-dimensional, in the index of refraction between different constituent elements of said PBG structure, its geometry, and spacing associated with an arrangement of said constituent elements, and shapes of said constituent elements.

14. The method of Claim 13 wherein said material comprising said PBG structure is selected from the group consisting of inverse opal backbone, macroporous silicon, colloidal crystals, woodpile structure, Yablonovite, and the like.

15. The method of Claim 11 wherein said excited electrically neutral species is selected from the group consisting of positronium, antimuonium, antihydrogen, protonium, molecular positronium, molecules containing positronium, positronium molecules bound to ordinary matter, and electrically neutral molecules containing a positron having a single positive charge bound to ordinary matter having a single negative charge.

16. The method of Claim 11 wherein the step of said introducing is selected from one of the following three methods:

(a) injecting said antimatter from radioactive sources or accelerator sources through a velocity moderator, either located within said PBG material of said PBG structure, or located outside said PBG structure;

(b) pair-producing positrons and electrons by high-energy gamma rays generated by electron beams or as a by-product of neutron capture processes, wherein said neutrons impinge on said PBG structure in a collimated beam, or said PBG structure is placed inside a nuclear reactor in which there is an abundance of neutrons; or

(c) embedding a radioactive material that emits positrons said PBG structure, resulting in a "self-charging" device, wherein a positron is introduced into said PBG structure, picks up an electron at said wall of said cavity, and becomes a positronium atom within said cavity.

17. A method for exciting antimatter species to an excited state, comprising:

providing an antimatter excitation device comprising a three-dimensional or two-dimensional photonic bandgap (PBG) structure containing at least one PBG cavity therein, said PBG cavity containing a quantity of species selected from the group consisting of excited electrically neutral atoms and molecules of antimatter, and excited electrically neutral atoms and molecules of exotic matter;

introducing said species into said at least one PBG cavity; and

exciting said species.

18. The method of Claim 17 wherein said PBG structure comprises materials and geometry that together provide bandgaps at frequencies specific to each species to be stored in said antimatter storage device.

19. The method of Claim 18 wherein said PBG structure has behavior that is dependent on a periodic contrast, wherein said periodic contrast is one-dimensional, two-dimensional, or three-dimensional, in the index of refraction between different constituent elements of said PBG structure, its geometry, and spacing associated with an arrangement of said constituent elements, and shapes of said constituent elements.

20. The method of Claim 19 wherein said material comprising said PBG structure is selected from the group consisting of inverse opal backbone, macroporous silicon, colloidal crystals, woodpile structure, Yablonovite, and the like.

21. The method of Claim 17 wherein said electrically neutral species is selected from the group consisting of positronium, antimuonium, antihydrogen, protonium, molecular positronium, molecules containing positronium, positronium mole-

cules bound to ordinary matter, and electrically neutral molecules containing a positron having a single positive charge bound to ordinary matter having a single negative charge.

22. The method of Claim 17 wherein the step of said introducing is selected from one of the following methods:

(a) injecting said antimatter from radioactive sources or accelerator sources through a velocity moderator, either located within said PBG material of said PBG structure, or located outside said PBG structure;

(b) pair-producing positrons and electrons by high-energy gamma rays generated by electron beams or as a by-product of neutron capture processes, wherein said neutrons impinge on said PBG structure in a collimated beam, or said PBG structure is placed inside a nuclear reactor in which there is an abundance of neutrons; or

(c) embedding a radioactive material that emits positrons in said PBG structure, resulting in a "self-charging" device, wherein a positron is introduced into said PBG structure, picks up an electron at said wall of said cavity, and becomes a positronium atom within said cavity.

23. The method of Claim 17 wherein said method of exciting said species is selected from one of the following methods:

(a) using a laser tuned to an energetic state outside said PGB structure to place said species in said excited state;

(b) creating said excited species in a more highly excited state that cascades down to the proper excited state, from which further decay is inhibited by said surrounding PBG structure; or

(c) achieving said excited state directly during formation of Ps*, employing radioactive sources that exhibit β^+-decay embedded in said PBG structure, such that as emitted high-energy positrons traverse said PBG material, they are slowed, and as they pass through said cavity wall, they capture an electron and form positronium in a Rydberg state, which can be said excited state or which can be a state of higher energy that cascades down to said excited state, or it can be a state of lower

energy that is laser pumped up to said excited state or up to a state of higher energy than said excited state and subsequently allowed to cascade down to said excited state.

24. A state of antimatter comprising a three-dimensional or two-dimensional photonic bandgap (PBG) structure containing an array of PBG cavities in said PBG structure, each PBG cavity separated from its nearest-neighbor cavities by a distance that is less than the photon localization length, each cavity containing a quantity of species selected from the group consisting of excited electrically neutral atoms and molecules of antimatter, and excited electrically neutral atoms and molecules of exotic matter.

25. The state of antimatter of Claim 24 wherein said PBG structure comprises materials and geometry that together provide bandgaps at frequencies specific to each species to be stored in said antimatter storage device.

26. The state of antimatter of Claim 25 wherein said PBG structure has behavior that is dependent on a periodic contrast, wherein said periodic contrast is one-dimensional, two-dimensional, or three-dimensional, in the index of refraction between different constituent elements of said PBG structure, its geometry, and spacing associated with an arrangement of said constituent elements, and shapes of said constituent elements.

27. The state of antimatter of Claim 26 wherein said material comprising said PBG structure is selected from the group consisting of inverse opal backbone, macroporous silicon, colloidal crystals, woodpile structure, Yablonovite, and the like.

28. The state of antimatter of Claim 24 wherein said electrically neutral species is selected from the group consisting of positronium, antihydrogen, protonium, antimuonium, molecular positronium, molecules containing positronium, positronium molecules bound to ordinary matter, and electrically neutral molecules containing a

29. The state of antimatter of Claim 28 wherein said excited positronium comprises an electron and a positron bound together in orbit, but separated by a first distance, and wherein said excited positronium is separated from said cavity wall by a second distance.

30. The state of antimatter of Claim 29 wherein said first distance is large enough to prevent self-annihilation but small enough to keep said electron and said positron in orbit about each other, and wherein said second distance is large enough to prevent contact of said excited positronium with said cavity wall.

31. A stable form of exotic matter comprising excited states of positronium (Ps*) confined within cavities in a photonic bandgap (PBG) structure, isolated from other electrons.

32. The stable form of exotic matter of Claim 31 wherein said excited states of positronium are placed in a Bose-Einstein Condensate (BEC) form in order to increase density of said confined material.

33. The stable form of exotic matter of Claim 31 wherein occurrences of the life-time-shortening pickoff process, wherein Ps* interacts with electrons at the cavity wall, can be substantially reduced by said PBG structure.

34. A combination of localized photons and partially excited species to form a stationary-state superposition thereof, or a stable photon-species-cavity bound state, formed by an excited electrically neutral species of antimatter or exotic matter interacting with cavity walls of a cavity located within a photonic bandgap (PBG) structure, said interaction being mediated by photons.

35. The combination of Claim 34 wherein said species is excited positronium (Ps*), which develops a very long lifetime, because it will remain in an excited state,

which prevents self-annihilation from ground state, said lifetime being at least a few seconds.

36. The combination of Claim 35 wherein said lifetime is extendable by proper selection of angular momentum for the excited state Ps*, said lifetime being at least a few seconds.

37. The combination of Claim 35 further including externally applied crossed electric and magnetic fields to substantially enhance said lifetime extension.

38. A method of releasing gamma ray radiation, comprising:

providing an antimatter excitation device comprising a three-dimensional or two-dimensional photonic bandgap (PBG) structure containing at least one PBG cavity therein, said at least one PBG cavity containing a quantity of excited positronium; and

perturbing said PBG structure such that the index of refraction contrast, the geometry, the spacing, and/or the shape of the constituent components changes in such a way as to shift or turn off the bandgap that is responsible for maintaining the positronium in an excited state to thereby release said gamma ray radiation.

39. The method of Claim 38, wherein said released gamma rays either have a fixed energy of 511 keV per gamma ray for two gamma rays per positronium atom or have a distribution of energies ranging up to approximately 1 Mev for three gamma rays per positronium atom.

40. The method of Claim 38 wherein said excited positronium decays to its ground state, forming a mixture of spin singlet and spin triplet states, which mixture of states produces self-annihilation from both spin states, resulting in a mixture of atoms producing two 511 keV gamma rays and atoms producing three gamma rays with a total energy of approximately 1 MeV.

41. The method of Claim 40 wherein a 203 GHz gamma ray pulse is applied to the trapped positronium atoms to de-excite said atoms in said spin triplet state to said spin singlet state, thereby enhancing production of two 511 keV gamma rays per atom and reducing production of three gamma rays with total energy approximately 1 MeV per atom.

42. A beam of species comprising excited electrically neutral atoms or molecules of antimatter or excited electrically neutral atoms or molecules of exotic matter emitted by a photonic bandgap (PBG) structure containing at least one PBG cavity therein, said at least one PBG cavity containing a quantity of said species, said beam comprising said species channeled out of said PBG structure into a desired direction by opened linear defect waveguides in said PBG structure.

43. A particle beam comprising electrically charged antimatter emitted by a photonic bandgap (PBG) structure containing at least one PBG cavity therein, said PBG cavity containing a quantity of excited electrically neutral atoms or molecules of antimatter or excited electrically neutral atoms or molecules of exotic matter, said excited electrically neutral atoms or molecules then ionized by an electric field, with electric and magnetic fields used to direct the ions out of the PBG device.